Non-Chrome Coating Systems for Aerospace

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Background

The replacement of hexavalent chrome [Cr (IV)] in the processing of aluminum for aviation and aerospace applications remains a goal of great significance within the aviation and aerospace community. Aluminum, being the major manufacturing material on structures and components in both the aircraft (military and commercial) and space flight arena, consequently, the processing and maintenance of this material against degradation and corrosion is of prime importance to the US Air Force and NASA in preserving our defense and space operations capabilities.

Key to the operability and preservation of aluminum has been the use of chromated systems (conversion coatings, primers and hard chromium plated). Hard chrome plating on components is done through an electrochemical process; the electrochemically adhered chrome provides barrier protection to the substrate by forming a dense self-healing oxide layer on the surface. The electroplated chromium is chemically resistant to most compounds and offers excellent corrosion protection. Hard chrome plating also confers increased wear resistance and is most frequently used on landing gears, actuators, gearboxes, rotor heads and other high impact/wear components. Conversely, with applied coatings, the high corrosion resistance offered by chromated films is attributed to the presence of both hexavalent and trivalent chromium in the coating. The trivalent chromium is present as an insoluble hydrated oxide, whereas the hexavalent chromium imparts a “self-healing” character to the coating during oxidative (corrosive) attack. Hexavalent chrome coatings also play a critical role in supporting and enhancing the adhesion of the primer coating to the substrate.

While chromated systems (applied coatings and plated) have set the bar for treatment and protection of aluminum, it is now known that hexavalent chromium is carcinogenic and poses significant risk to human health. The current Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for chromium is 52 µg/m3, but OSHA is expected to reduce the PEL for hexavalent chromium.

OSHA studies have determined that hexavalent chrome poses significant medical risks to users. Hexavalent chromium is considered a potential lung carcinogen; studies of workers in the chromate production, plating, and pigment industries consistently show increased rates of lung cancer. It has also been shown that direct eye contact with chromic acid or chromate dusts can cause permanent eye damage. Hexavalent chromium can irritate the nose, throat, and lungs and repeated or prolonged exposure can damage the mucous membranes of the nasal passages and result in ulcers. In severe cases, exposure causes perforation of the septum (the wall separating the nasal passages). It has also been proved that prolonged skin contact can result in dermatitis and skin ulcers. Some workers develop an allergic sensitization to chromium and kidney damage has been linked to high levels of dermal exposures.

OSHA recently lowered the PEL for hexavalent chromium in construction, shipyards, and general industry from 52 to one (5) microgram of Cr (VI) per cubic meter of air as an 8-hour time weighted average. The proposed rule also includes provisions for employee protection such as preferred methods for controlling exposure, respiratory protection, protective work clothing and equipment, hygiene areas and practices, medical surveillance, hazard communication, and recordkeeping. In the interest of worker safety, as well as the cost and operational implications of new and pending environmental, safety and health regulations, both NASA and the US Department of Defense (DoD) continue to search for an alternative to hexavalent chrome in coatings plating applications that meet their performance requirements in corrosion protection, cost, operability, and health and safety; while underlining that performance must be equal to or greater than existing systems.

Objective

Evaluate and test a fully non-chromated coating systems (pretreatment, primer and topcoat) as replacements for hexavalent chrome coatings in aircraft and aerospace applications.

Period of Performance

- October 2005 to May 2009.

Stakeholders

NASA Centers (Kennedy Space Center, Marshall Space Flight Center); Space Shuttle Elements/contractors (Boeing-Orbiter, Reusable Solid Rocket Motor, United Space Alliance); Shuttle Environmental Assurance initiative, and U.S. Air Force (Hill Air Force Base, Air Force Materials & Manufacturing Directorate at Wright Patterson Air Force Base).

Benefits

- Meets environmental and safety regulatory requirements
- Reduces need to monitor for chromium exposure due to new regulations
- Decreased risk of environmental, worker and public exposure
- Reduced maintenance cost and government liability
- Addresses NASA and Air Force requirements on aluminum alloys 2219, 2195, 6061, 2024 Bare, 2024 Clad, and 7075.

Document Status

- Draft Joint Test Protocol and Joint Test Report will follow on into Phase II Reporting.

Recent Progress

- NASA FY2006 funds allocated to support testing work being performed at Hill Air Force Base, Kennedy Space Center, Boeing Huntington Beach and Marshall Space Flight Center and Wright Patterson Air Force Base.
- Hill Air Force Base cut and coated all test panels. They were then shipped to facilities for testing:
    - Filiform Corrosion Testing (1,000 hour test started January, 16, 2007) - Kennedy Space Center
    - Salt Spray Corrosion Test (3,000 hour test started December 20, 2006) - Hill Air Force Base
    - Adhesion Testing (will begin in April, 2007) – Hill Air Force Base
    - Cyclic Corrosion Testing (3-phase 1,000 hour test began Jan 21, 2007) – Marshall Space Flight Center
    - Simulated Aircraft Structure (SAS) Box Corrosion Testing (run-to-failure test began October 30, 2006) - Wright Patterson Air Force Base
    - Dissimilar Metals (Sandwich) Corrosion Test (2,000 hour test began Jan 8, 2007) – Boeing, Huntington Beach

Milestones

- Completed Filiform Corrosion tests - February 2007
- Completed Dissimilar Metals (Sandwich Corrosion) – March 2007
- Completed SAS box corrosion tests are complete United States Air Force/ Air Force Research Laboratory. – May 2007
- Completed Cyclic Corrosion – June 2007
- Completed Salt Fog Corrosion Testing (2,000 hours) – October 2007
- Completed Adhesion Testing – October 2007
- Identified Three Systems for Down-Selection to Atmospheric Testing (Phase II) – November 2007
- Received all test reports except Air Force – SAS Box Test Report – September 2008
- Completed Statistical Analysis of Cyclic Corrosion Testing – December 2008

Near-Term Goals

- Complete individual test reports and submit for International Traffic in Arms Regulations approval.
- Close out project with summary report of all testing and results.

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